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# ON NOT BEING CREATIVE. HOW REVERSE ENGINEERING DEVELOPS COMPETENT DESIGNERS

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**ABSTRACT**
The paper sets out to describe the somewhat uncreative approach taken by London South Bank University design students as they first tackle issues of producing two-dimensional CAD drawings of products. This process is contrasted with so-called creative processes, and is aiming at producing mastery or competency within the students. The paper starts by describing creativity and mastery, and then describes the CAD exercises and the outcomes of them.

*Keywords: Creativity, Mastery, 2-dimensional CAD, Visual thinking*

## 1 INTRODUCTION
Design is about being creative. Or is it? This paper starts off by taking a brief look at what are taken to be the traditional components of creativity and then looks at the perhaps contrasting topic of mastery. The thesis of the paper is that when we are teaching design we need to include the development of a series of skills that are more closely aligned to the copying of mastery than they are to the concepts of creativity. It is almost as a by-product of developing these skills that creative abilities can be utilised.

## 2 BEING CREATIVE
The approach taken by several books on the subject is that developing creativity is all about thinking differently. Phrases such as ‘out of the box’ and ‘being zany’ indicate that creativity equates with weird and different thinking styles that leaves a trail of debris to be vacuumed up after the creative thinker has left. This is an exaggeration, but books such as Roger von Oech’s *A Whack on the Side of the Head* [2] seem to build up that impression. Creativity is an unconventional take on life, and on the confronting problem. Creative people are apt to be untidy, go round breaking rules and being slightly outlandish.

### 2.1 Tests for creativity
Tests for how creative a person might be include finding as many uses as possible for a house brick, a bucket, a banana and so on, allowing anything to be acceptable, no matter how strange it might appear. As many different ideas as possible are wanted, with the next found quickly and with no development or practicality. For creativity to be at its highest, ideas have to be many and varied. In some cases creativity is demonstrated by how convoluted puzzles are solved and how quickly a

varied range of influences can be brought to bear on a hypothetical problem such as joining up dots.

### 2.2 The nature of creativity

These puzzles leave some otherwise highly creative people cold. For them creativity is more about the reality of application within the context of novelty in whatever specialist area they work. Creativity is significantly more complicated than this, as any encounter with a text such as Sternberg’s *The Nature of Creativity* [3] will demonstrate. Whilst Sternberg’s collection does include aspects of creativity similar to these, there is a real attempt to look at how people develop creative thinking skills and ways of operating in an environment where creating takes place.

Not only is creativity associated with doing something novel, it is also associated with getting something to work. Part of this is in the doing. If the thing is not followed through from idea into some form of embodiment, then all the techniques to think up the good ideas are not much use.

So a book such as Geoffrey Petty’s *How to be better at… creativity* [4] sets creativity in the context of achieving creative outcomes. Petty has a set of processes described by the Mnemonic ICEDIP: Inspiration, Clarification, Evaluation, Distillation, Incubation and Perspiration. Of these, inspiration is perhaps the only one of these that is obviously a creative process producing many and varied ideas. In Petty’s scheme, inspiration is concerned with getting as many ideas down as possible. Here he again focuses on the outcome of the process – getting ideas down – talking about improvisation as a prime means of inspiration. Here the output evolves and develops, with themes modified by elaboration, sub-themes, variations, upside-down tunes and so on contributing towards a coherent outcome – through other process-stages. In this stage there is the acceptance of some messiness. Ideas are half-baked, semi-formed and incomplete: we are dealing with possibilities rather than a set of answers that all work. But these are firmed up during later stages.

### 2.3 Making creativity evident

Students need to be creative. But that is not all. There needs to be a balance between the zaniness and concrete, defined abilities that need to be developed so students become part of a coherent three-dimensional design profession.

The two go hand in hand; basic skills of visualisation, manufacture and idea-reality confirmation need to be developed in conjunction with creativity.

### 2.4 Adding creativity to basics

For those who don’t know how to do something, the ‘creative’ approach doesn’t work. If they try something different it looks amateur, in the worst sense of the word. Doing something different when you haven’t mastered the basics means that you are shown up as one who doesn’t know what you are doing. Usually. So back to the basics.

## 3 DEVELOPING MASTERY [5]

A related concept within education is that of mastery. The concept has two distinct aspects: one that has developed from a Japanese concept, and one that has come from a Western educational context.

### 3.1 Mastery as the Japanese concept

Apparently there is one word in Japanese that means both *to learn* and *to copy*. Checking this out with a Japanese post-graduate student confirmed that this was only half the story. The concept is that of mastery. Learning through copying the master. Being good at something means developing the mastery by copying the best example of that something. Minutely. This is a powerful process. It took the Japanese from copying the Austin Seven and BSA Bantam to road ownership in less than half the time the rest of the Motor Industry took to develop. (But why they chose the Austin Seven and the BSA Bantam is probably still a mystery.) The way in which it happened in the Japanese motorcycle and motor industries had the appearance of being a choreographed strategy for success. During this journey variations on the theme may not need to be developed until mastery is achieved, so creative skills may only be needed once mastery has been achieved. The Peter Principle [6] may be at work.

#### *3.1.1 The process*

The process involves locating an appropriate master from whom to copy. In apprenticeships and similar systems this would mean working with the master, copying the movements and processes until the apprentice became a professional, and then a master in their own right and able to take on apprentices themselves.

In teaching product design, although the lecturers might be role models, being masters is harder, although it is still practiced where a visiting professor may take master classes. (This seems to be particularly prevalent with performing arts and with music where the individual performer is significant). In practice, lecturers are seldom able to continue their industrial contacts so they are able maintain to mastery: and product design is a team effort so a single master is unable to demonstrate a wide range of skills.

The state-of-the-art in any particular area needs locating: perhaps a significant product. Methods of doing this will vary. These include developing a marketing map for the product area, including a features and parametric analyses to identify brand leaders [7]. These determine current thinking but don’t define ‘good’ design.

The product is then deconstructed so the minute detail of how it has been made can be understood. Not just understood, but copied in as close a detail as possible. This is difficult, because the mass manufacturing processes are simply not possible to be replicated, so a compromise has to be reached, relying on a combination of mastery and product deconstruction.

### 3.2 Mastery as a staged educational process

Another variation on the concept of mastery is related to correctly completing some skill. This might be an educational skill, such as spelling, or physical such as perfecting a movement in a sport like tennis. Mastery of one skill is needed before the next skill can be attempted. Students build up competence through building up mastery in a series of linked skills.

#### *3.2.1 The process*

This process requires that the teacher masters and is also able to determine the difference between correct performance and the learner’s current position. An effective feedback system is needed to make this judgement. The minute copying process of the Japanese mastery is contained within this concept, but the whole skill-set is broken down to develop a series of masteries. Some would describe this as de-skilling, but it is probably better to describe it as making the skill apparent.

#### *3.2.2 The output*

Creativity is stripped away for a positive outcome in skills development. Building up competence in building blocks is an important precursor to the development of creative design skills. Students move from early learners to professional practitioners.

## 4 RELATIONSHIP WITH REALITY

For product design, perhaps the key mastery ingredient is to be able to relate ‘thinking space’ to reality. This may be via a two-dimensional representation, or may be via a three-dimensional model, or by a combination of both. Products relate to marketing and sales, but also relate to the possible and what works in practice. Thus, even if an engine design were designed using marketing principles such as features and parametric analysis, it must actually function well. The physics and chemistry must be right.

### 4.1 Reverse engineering

One process for developing this understanding of how the real world works is reverse engineering. This takes its cue far more from the educational concept of mastery than the Japanese one. Originally, this was construed as copying in the worst possible way for the worst possible of reasons – obtaining an unfair advantage over the competition by deconstructing exactly how their products were made to sell illegal copies. The term is still used in this context in the case of software design. The term is also used in the CAD for the process of scanning a component or product to produce a series of points known as a points cloud and turning this into a mathematical surface description.

### 4.2 Reverse engineering in education

However, in education, reverse engineering can be a powerful process towards understanding how products function and are constructed. When it is combined with CAD design it prevents the latter from being virtual, and allows students to develop educational-type mastery skills in three-dimensionality. Students always need to return to the thing and comparing someone else’s product with their presumed process validates it. The value of design for a particular product can only be realised once it ceases to be an idea and becomes a physical embodiment, and the lesson of repeatedly comparing the manufactured object with the CAD work that is their output develops three-dimensional competence and mastery.

## 5 REVERSE ENGINEERING EXERCISES

The purpose of these is to develop two- and three- dimensional skills in students when they first arrive on their courses. The first year students have been given two reverse engineering exercises. These are related to the development (and eventual mastery) of 2-dimensional drafting and 3-dimensional visualisation skills. In practice, these exercises probably achieve the development of competence rather than mastery.

CAD is power. This is a feeling that seems to pervade the suppliers, but is lacking reality. In order to benefit from CAD the user has to have a reliable understanding of the relationship between two and three dimensions: and a knowledge of the relationship between the designed plan for an object and its eventual embodiment. This means that two- and three-dimensional perceptive skills need to be present as well as a detailed knowledge of the particular computer package. Either one without the other is insufficient.

When many degree courses are moving directly to three dimensional work, it may be valid to ask why two dimensional drafting is still used. In practice, although a proportion of products are now created solely from 3-dimensional digital databases there is still are large amount of industrial work output to subcontractors who use 2-dimensional drawings, so students have to learn how to be competent at using it. And if they need to get something made quickly, then it is the relationship between the plan and intention that appears on paper with a pencil that is more readily available than a 3-dimensional database. Design team meetings tend to be based around sketches and doodles rather than computers – they work better for interactive discussion. This approach is best understood using an analogy – students should consider their drawing has to be sent for quotation to a model maker or a subcontract engineering firm with the contact at the company an “old school engineer”, who is schooled in drawing standards rather than 3-dimensional CAD. The drawing has to be to standard so that it can be understood without jumping to conclusions; it has to have the appropriate paper space and text size so that when faxed it still is legible and it has to be dimensioned adequately so the subcontractor doesn’t counter-charge for phone calls he’s made to ask for dimensions, although admittedly this is a worst case scenario – however, it is preferable for the students to also gain knowledge of the relationships between drawings and their users.

Primary sketching of orthographic layout and adding dimensions saves dual decision time: the processes of learning new software and of developing three-dimensional concepts in the mind are able to take place simultaneously. Students focus on decisions related to creating the drawing using the relevant commands rather than questions of what type of curve should be used and the mechanics of getting that done.

Students are encouraged to sketch out principal views of the item they are drawing on paper before inputting information into the software. The intention of this is to enable them to solve any layout issues before committing to draw on screen and potentially saves time at a later date.

### 5.1 The first exercise

The first exercise is for students to take their mobile phone and to produce an outline engineering drawing of it as if they were producing the drawing for someone manufacturing a block model of it. By choosing the students mobile phone the intent was to alleviate the “Oh! I left it home” scenario. Additionally, students involved would almost certainly posses a wide range of handsets, which could act as an aid to prevent plagiarism due to each student drawing a single source artefact and copying the drawing electronically rather than going through the drawing process.

This is, of course, not the way that such a phone would be drawn or designed in industry. In terms of its reverse engineering content, this is like the process to obtain a points cloud.

### 5.2 The second exercise

The next item was more complicated in detail due to the linked assignment. It was to produce a complete set of component and assembly drawings for an audio cassette. The Audio cassette had to be disassembled, a parts tree created, a general assembly and set of parts drawings had to be drawn, labelled and dimensioned. In essence the work load on this element may seem to be a huge amount of work to the student: however, considering the use of layers, cut and pasting and so on the largest area for work is potentially the dimensioning and drawing of the layout.

### 5.3 Output and comments

Students inevitably find that the discipline of getting down to drawing is difficult. They are used to some vague sort of drawing that seems to be determined as a visual picture rather than as an essential design and manufacturing ingredient. They are not used to precision. They have also not used 3-dimensional visualisation skills before. To see a student holding the product up to the screen to see if he had drawn it at the right scale, whilst being comical, indicates that thinking is being developed.

Once students have finished the reverse engineering exercises they can use the skills to create their own product vision, developing the manufacturing process and parts lists in a similar way.

## 6 CONCLUSIONS

If we have undue emphasis on the use of new technology we are missing something. The old ways worked reasonably well. New technology is available and we do need to use it, but understand that the output from the overall design process is not an untested three dimensional computer rendering, but has to be a product that can be held in the hand; used, abused and misused – that has to be assembled, maintained and so on.

With our emphasis on creativity we may also be missing skills that designers developed through touching, feeling and being with artefacts. Developing skill sets is about providing a coherent set of skills to master. Creativity can be added to this – and eventually they can become masters of their own creations, in the way that the Japanese have mastered some areas of manufacturing industry.

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